
Overview of the Reconnection Scaling Experiment at LANL and first experimental results

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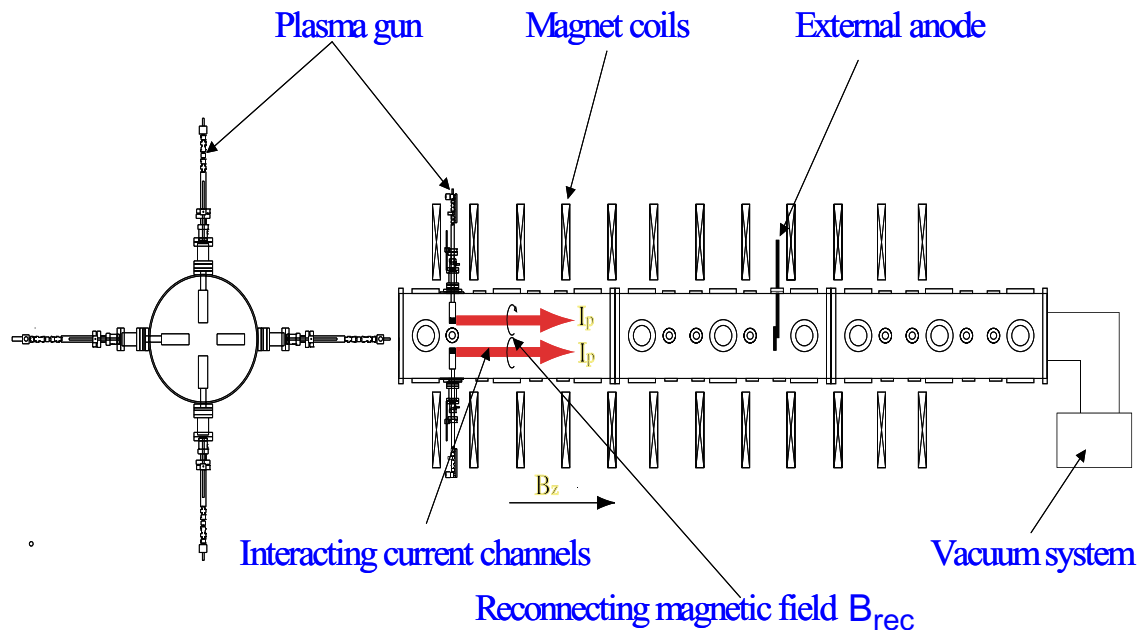


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Abstract

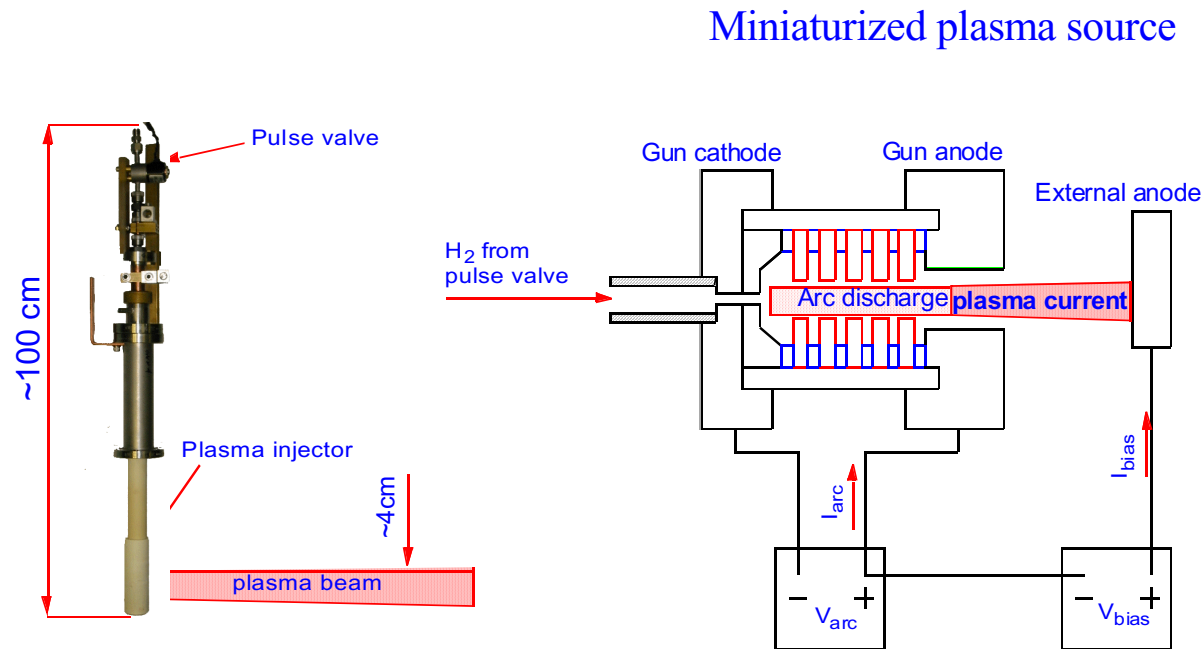
- Three dimensional magnetic reconnection is a major issue in both astrophysical and laboratory plasmas.
- The Reconnection Scaling Experiment (RSX) is a new device for the study of 3D magnetic reconnection at LANL.
- RSX relies on plasma gun technology to generate high density (10^{14} cm^3), high current ($J \sim 100 \text{ A/cm}^2$), ohmically heated ($T_e \sim 10\text{-}20 \text{ eV}$) plasma channels.
- The machine design is reviewed. First experimental results on the interaction of two current channels are presented.

RSX: device and plasma guns (1)



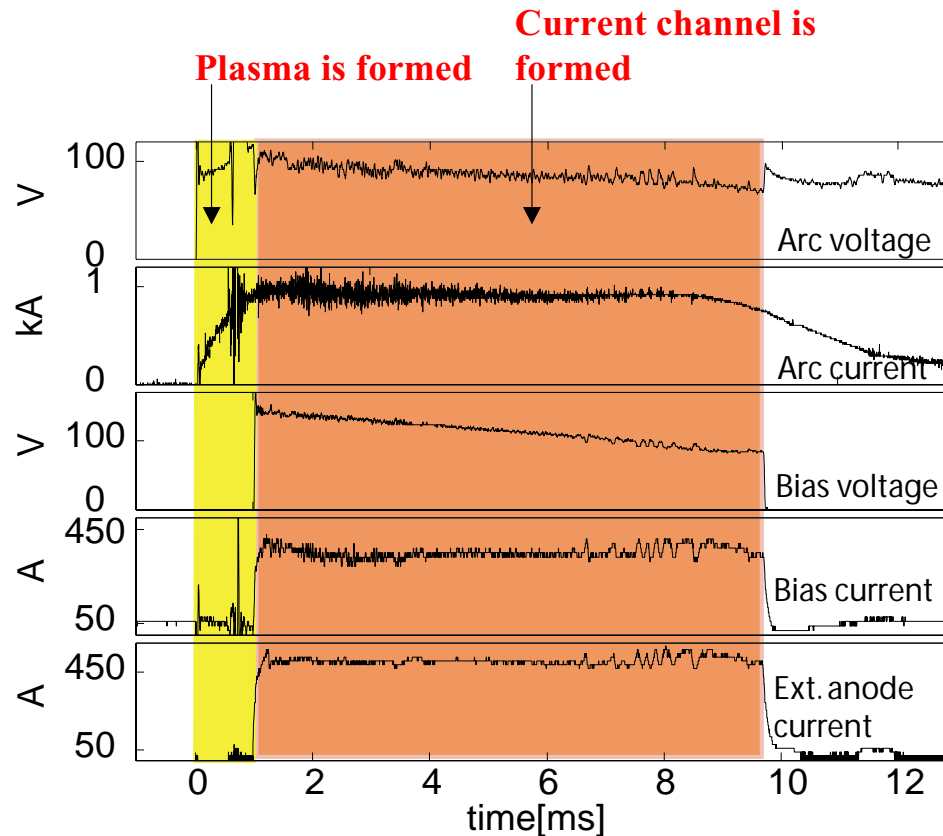
- Parallel current channels are produced using 4 plasma guns, movable in the radial direction.
- Linear vacuum vessel (~ 4 m length, 50 cm diameter), good accessibility \Rightarrow ease of diagnostics.
- 12 magnet coils, 0.1 F, 700 V, SCR switched capacitor bank $\Rightarrow B_z < 1000$ Gauss.

RSX: device and plasma guns (2)



- Plasma guns produce:
 $V_{\text{bias}}=0 \Rightarrow$ stream of neutral plasma
 $V_{\text{bias}} \neq 0 \Rightarrow$ current channel
- Gun arc and bias are energized by SCR switched capacitor banks:
 $V_{\text{arc}} \sim 100 \text{ V}$, $I_{\text{arc}} = 0.3-1 \text{ kA}$, $V_{\text{bias}} = 0-300 \text{ V}$, $I_{\text{bias}} < 1 \text{ kA}$.

Typical discharge sequence



- Duration of arc discharge is ~10 ms.
- Duration of bias discharge can be varied between 0.5 to 8 ms.

RSX advantages and plasma parameters

- Plasma guns are a reliable technology (to date > 1000 shots) to create current channels \Rightarrow excellent shot to shot reproducibility.
- Linear geometry allows a truly 3D reconnection experiment.
- Important plasma parameters can be scaled independently:

density is controlled by gas plenum (5 – 50 Psi) $\Rightarrow n_e \sim 10^{12}\text{-}10^{14} \text{ cm}^{-3} \Rightarrow$

$\delta_e \sim 0.3\text{-}2 \text{ mm}$, $\delta_i \sim 1\text{-}7 \text{ cm}$

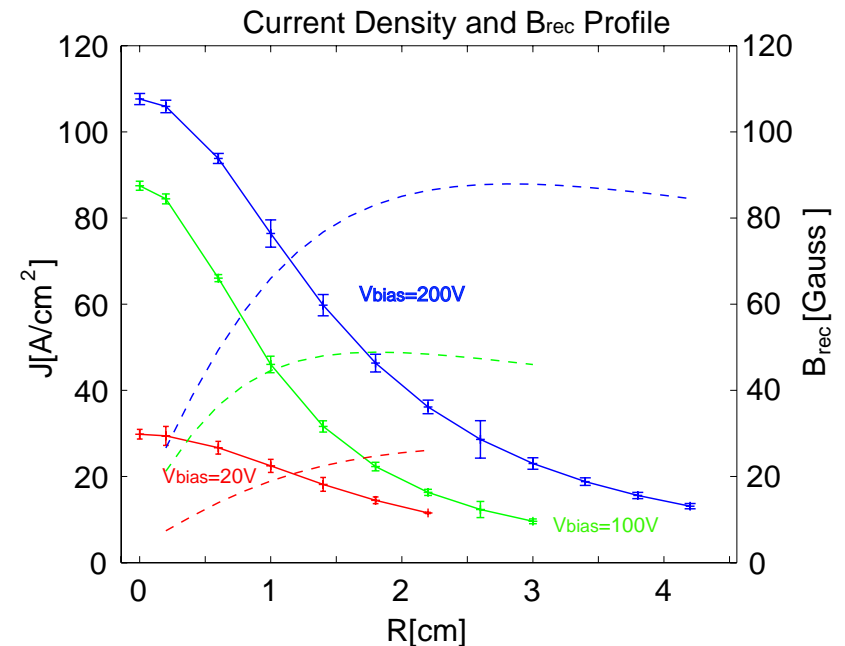
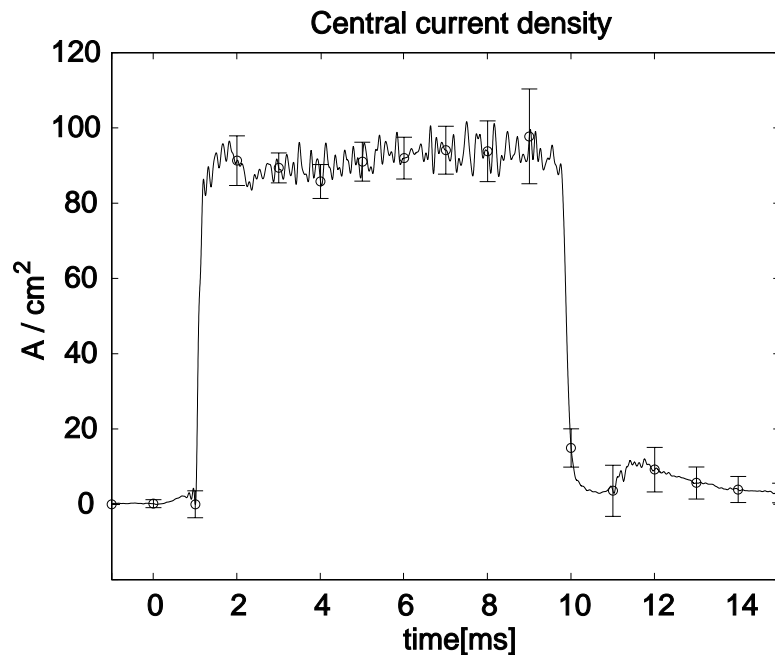
plasma current and B_{rec} are controlled by $V_{\text{bias}} \Rightarrow B_{\text{rec}} < 100 \text{ Gauss}$

plasma channels are ohmically heated $\Rightarrow T_e \sim 10\text{-}20 \text{ eV}$, $S \sim 800$.

Main diagnostics

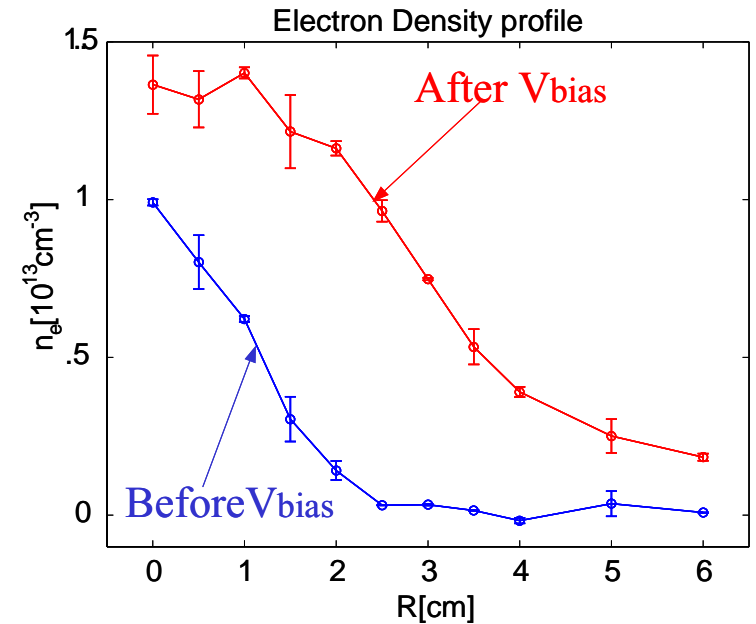
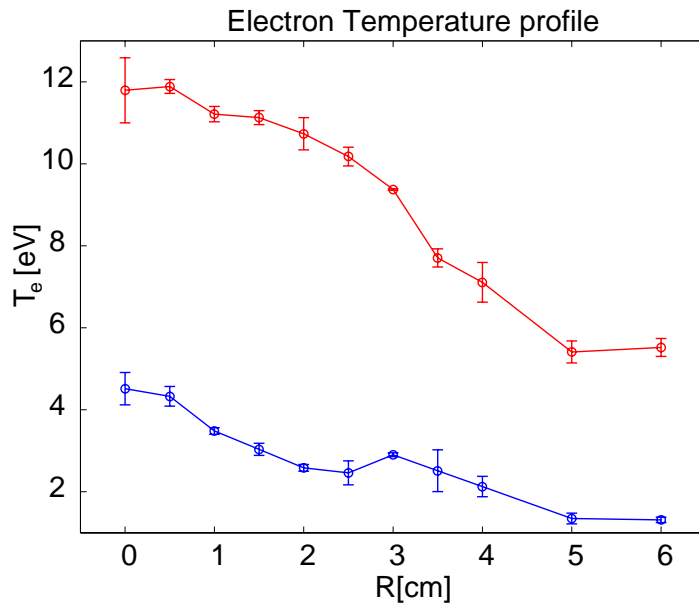
- Miniaturized Rogowski probe \Rightarrow current channel profile
0.7 cm² detecting area, time response 100 ns
- Three dimensional magnetic probe
3.75 mm ID, 30 turns each, time response 100 ns
- Fast CCD Phantom 4 camera \Rightarrow visible light emission
8000 frames/s, 20 ns minimum exposure time, 256*256 pixels
- Triple electrostatic probe \Rightarrow T_e , n_e profile and fluctuations
shot averaged I-V traces, real time T_e measurement
- Plans for the future:
3 axes movable probe drive \Rightarrow 3D scan of reconnection region

Characterization of current channels (1)



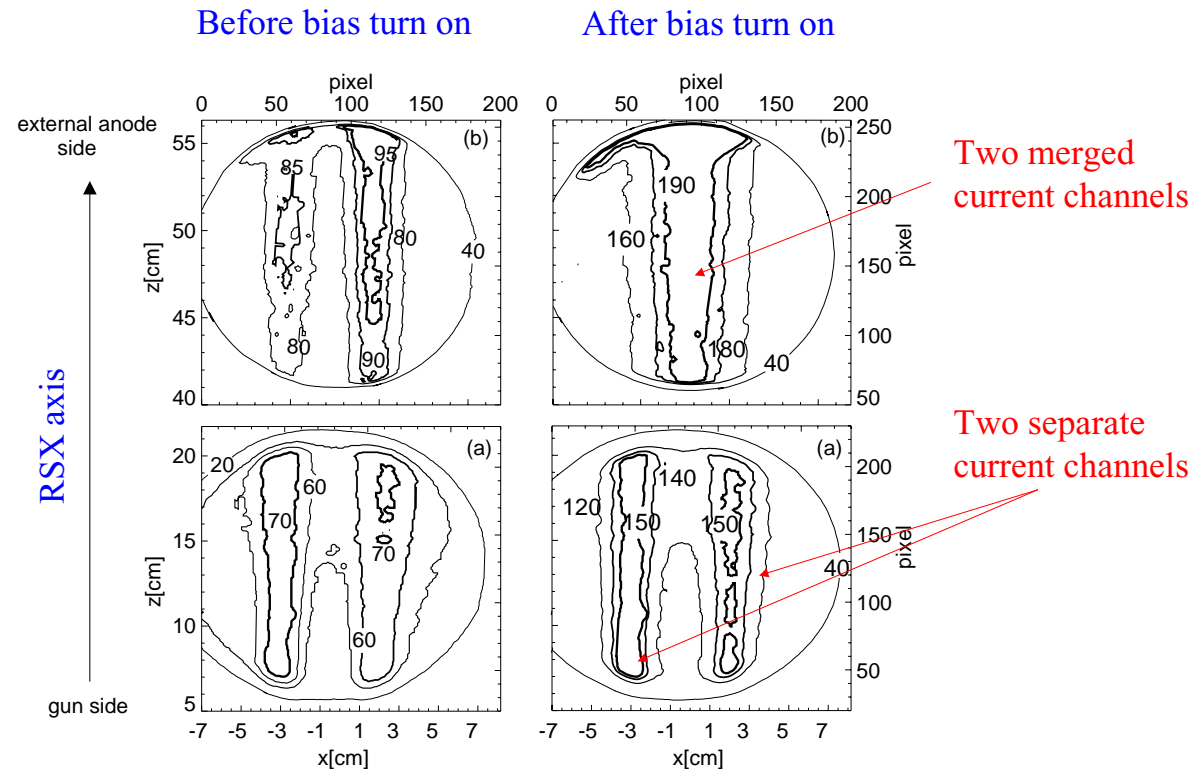
- **Excellent shot to shot reproducibility:** 10 consecutive discharges show a reproducibility of $\sim 7\%$ in the plasma current density. Data were taken with a Rogowski probe at 100 cm away from the plasma gun.
- Reconnecting B_{rec} is decoupled from B_z and can be scaled by changing V_{bias} .

Characterization of current channels (2)



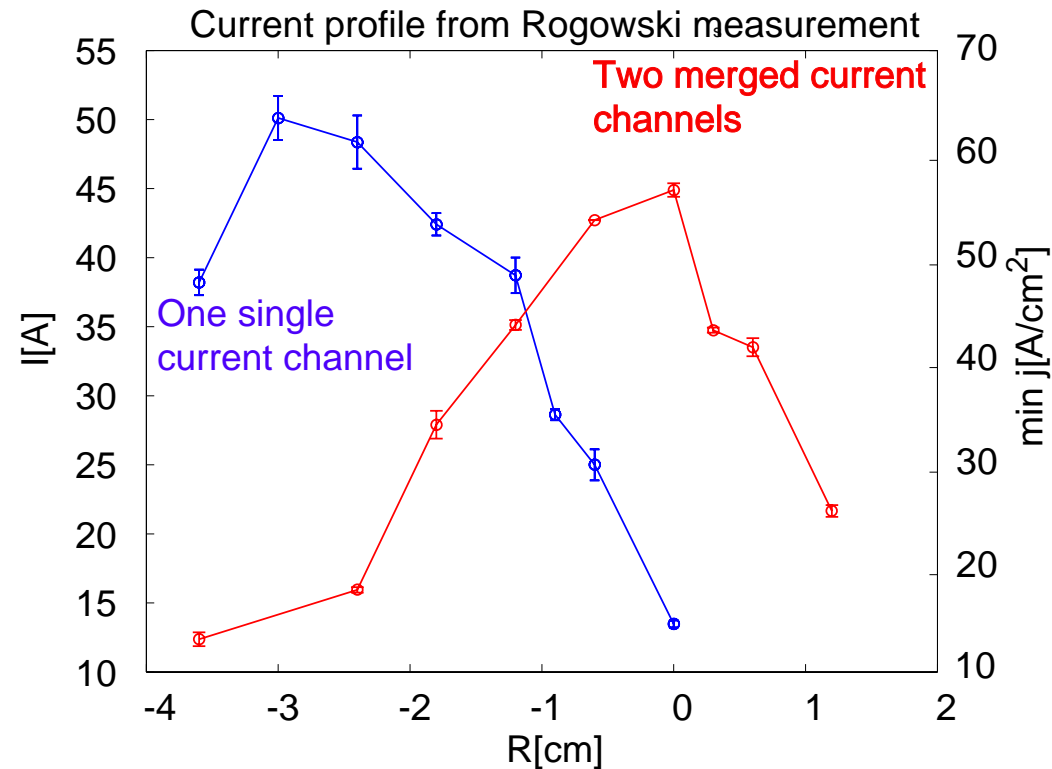
- The plasma column is ohmically heated by the plasma current.
- **Electron-neutral collisions are negligible:** plasma column is ~50% ionized in this experiment. $\tau_{ei} \sim 8-80$ ns for $T_e \sim 10-20$ eV, $\langle \sigma v j \rangle_{en} \sim 1.2 \cdot 10^{-7}$ cm³/s, $\tau_{en} \sim (7 - 70) \cdot \tau_{ei}$

Experiments with two plasma guns: evidence for current channel merging (1)



- Fast images (270 μ s frame to frame, 55 μ s exposure time) of visible light emission with two plasma guns \Rightarrow merging of the two current channels along RSX axis.

Experiments with two plasma guns: evidence for current channel merging (2)



- Current profile measurement show one single merged current channel at $z=50$ cm (large flux annihilation?).

Summary

- RSX is a new laboratory experiment for studying 3D magnetic reconnection.
- The innovative plasma gun technology is used to create interacting current channels in linear geometry allowing a fully 3D reconnection experiment.
- A wide variety of plasmas can be created and plasma parameters can be scaled independently which are crucial for reconnection physics.
- Preliminary visible light emission and current profile measurements during the interaction of two current channels show coalescence of the current channels.
- Plan for the future: 3D reconnection region will be studied.